

PROCESS FOR SHARED LONG-DISTANCE TRANSMISSION BY OPTICAL FIBER

[0001] The present invention relates to the area of transmissions of signals on a line between a transmitter and a receiver.

[0002] The present invention relates more particularly to the long-distance transmission of the signal on a connection comprising a succession of several segments of optical fiber of approximately 100 kilometers.

[0003] The transmission of signals by optical fibers over long distances meets problems of attenuation and of chromatic dispersion. Thus, a signal that is very monochromatic at the beginning of the line will be dispersed and will no longer have sufficient level at the end of the line to be correctly reconstituted. The result is therefore a loss of information.

[0004] The first techniques used to resolve this problem were to install signal regeneration stations. The signal is first converted to an electronic signal, regenerated and retransmitted. This regeneration system was very expensive for a single transmission channel and thus for a single transmission wavelength.

[0005] Another known solution is that of optical amplification. The chromatic dispersion of the wavelength is compensated by a fiber of opposing dispersion and the attenuation is compensated by an optical amplifier. This solution requires high-performance transmitters and receivers and remains expensive in single channel.

[0006] Moreover, in order to augment the number of signals to be transmitted on the line, multi-channel solutions rapidly became necessary. A plurality of transmitters uses different wavelengths. The data is then modulated to quasi-monochromatic signals and the quantity of information transmitted is thus augmented. The signals are then multiplexed before transmission

on the optical line. The amplification and the optical compensation are then realized simultaneously on the multiplex. This method has the disadvantage of using very expensive transmitters for each channel.

[0007] In the area of multiplexing in wavelength or WDM for Wavelength Division Multiplexing, the prior art already knows a device and a process for regenerating data in an optical transmission from patent application EP 1 233 567 (ALCATEL). The entering data stream is first demultiplexed by a demultiplexer in wavelength. Delays are then introduced in a specific manner for each channel, that is to say, the delayed signals are multiplexed again for each wavelength. The device comprises a modulator modulated by a high-frequency clock and comprises a photodetector for an automatic optical adaptation of the delay lines.

[0008] This process is a method of signal regeneration successively using a demultiplexing, then a multiplexing of the signals. The delays introduced are of the optical type by virtue of the photodetector.

[0009] It does not supply a solution for the shared transmission of different signals coming from a plurality of transmitters.

[0010] The present invention intends to remedy the disadvantages of the prior art by proposing a process of sharing performance for a long-distance optical transmission.

[0011] In order to do this, the present invention is of the type described above and is remarkable in its broadest meaning in that it supplies a process for the transmission of data on an optical fiber comprising a stage of multiplexing in wavelength of signals coming from a plurality of monochrome transmitters, each of which has its own wavelength, and a stage of modulation by the information to be transmitted by a carrier realized per channel, characterized in that the timing (clocking) of each of these transmitters is controlled by a common clock.

[0012] In addition, the process preferably comprises a stage of placing all the carriers in a common and simultaneous form.

[0013] The formatting [forming, shaping] stage advantageously consists of optimizing the form [shape] of the signal as a function of the characteristics of the propagation of the associated transport means.

[0014] The formatting stage advantageously consists of optimizing the optical parameters of the signal as a function of the characteristics of the propagation of the associated transport means.

[0015] The formatting stage advantageously comprises an operation of stabilizing the temporal parameters of the data stream.

[0016] In addition, the process preferably comprises a stage of synchronizing streams (pulses) emitted by said monochrome transmitters.

[0017] The formatting stage advantageously comprises an operation of aligning the phase of the signals generated by said transmitters.

[0018] According to an embodiment the alignment operation is subject to ambient parameters in order to compensate temporal signal variations.

[0019] According to another embodiment the alignment operation is subject to ambient parameters in order to compensate the differences and variations between the optical paths.

[0020] Each element of the multiplex is advantageously signed before the multiplexing stage by a frequency marker applied on the phase.

[0021] Each element of the multiplex is advantageously signed before the multiplexing stage by a frequency marker applied on the amplitude.

[0022] According to a first embodiment this marker is constituted by a signal presenting a predetermined spectrum.

[0023] According to another embodiment this marker is constituted by a signal presenting a spectrum whose characteristics are functions of the disturbances experienced by the signal on the corresponding path.

[0024] The characteristics of the marker are preferably determined in order to disturb the marked signal in such a manner that the marking is evanescent during the passage in the gate.

[0025] The present invention also relates to equipment for the transmission of data on an optical fiber, comprising a plurality of monochrome transmitters, each of which has its own transmission wavelength and a multiplexer, characterized in that it comprises a master clock controlling the slave clocks of each of these transmitters.

[0026] Moreover, the equipment advantageously comprises an optical gate that receives the multiplex of optical carriers as well as a cutting signal produced by this master clock.

[0027] It also preferably comprises frequency marking circuits for each element of the multiplex.

[0028] According to an embodiment each of these frequency marking circuits applies the marking signal onto one of the transmitters.

[0029] According to a second embodiment each of these frequency marking circuits applies the marking signal onto the synchronization means of each path.

[0030] The optical gate advantageously comprises means for detecting each marker in order to control the characteristics of the formatting and adjustment of the phase of the corresponding path.

[0031] The optical gate advantageously comprises means for the spectral analysis of the marker for the adjustment of the phase of the corresponding path.

[0032] The present invention also relates to equipment for the regeneration of data on an optical fiber of the opto-electronic conversion means, a demultiplexer and a clock connected to at least one of these converters.

[0033] The present invention also relates to a counter-reaction circuit for equipment for the transmission of data on an optical fiber, characterized in that it generates a frequency marker for injecting a disturbing spectral signal of a transmitter, and comprises means for the detection of the output signal of a gate for acting on means for the automatic control [slaving] of the transmitter phase for obtaining the desired spectral transformation of each marker.

[0034] The invention will be better understood with the aid of the following description, given solely by way of explanation, of an embodiment of the invention with reference made to the attached drawings.

[0035] Figure 1 shows a transmission scheme on an optical line through a wavelength comb in accordance with the prior art.

[0036] Figure 2 shows a transmission scheme on an optical line through a wavelength comb in accordance with the invention.

[0037] Figure 3 shows a synoptic scheme of equipment for the transmission of data on an optical fiber in accordance with the invention.

[0038] Figure 4 shows the case of a regeneration site in accordance with the invention.

[0039] Figure 5 shows the formation of a signal of the RZ type starting from the associated NRZ signal.

[0040] According to the prior art, illustrated in figure 1, the n transponders TX transmit according to different wavelengths. The signals are multiplexed by multiplexer M and then transmitted on long-distance optical line L. The n transponders should be high-performance transponders in order to permit the transmission.

[0041] According to the invention, illustrated in figure 2, the synchronization equipment associated with the counter-reaction loop permits the obtention of a sharing of the performances of the transponders. The quality of the signal is thus obtained after passage through the synchronization equipment in accordance with the invention, which permits the use of transponders of a lesser quality that are therefore inexpensive.

[0042] According to the invention, illustrated in figure 3, the equipment comprises the following functional subunits:

- Part of a transmission comprising a plurality of transponders 4 permitting a synchronization of the streams entering on the local timing [rate] coming from synchronization block 2.

- Multiplexer 5 receiving the signals on the input coming from each of the transponders and supplying a multiplexed signal.

- Optical gate 1 that ensures the formatting of the multiplexed signal.

- Synchronization circuit 2 that controls a clock of the optical gate as well as local clocks 11 of each of the transponders.

- Signal processing circuit 3 that supplies disturbance signals acting on the phase of the transponder clocks.

[0043] The transmission part implements N monochrome transponders. Each transponder supplies a colored optical signal with a specific wavelength. The carrier of each transponder is

modulated by the information to be transmitted in a known manner. Each transponder comprises a local clock 11. This local clock is a slave clock controlled by master clock 6 of synchronization circuit 2. The equipment can also comprise means for generating a data stream to be transmitted. Such a means obtains data and an associated frequency supplied by a clock with a period equal, in accordance with the application, to that of a binary data element.

[0044] A stage for the resynchronization of the data streams entering at a rate synchronous with the common clock is possibly necessary. This justification process is a known type.

[0045] The transponder of the invention also comprises, in a known manner, means for the modulation of an optical source by a signal coming from a data generator. The signal is also amplified in order to be electrically adapted to the components. The amplifiers can be low-cost within the framework of the invention.

[0046] Finally, the luminous source whose amplitude is to be modulated can possibly necessitate the use of a device for controlling the wavelength in the case of a WDM system.

[0047] The pre-accentuation of the level of each of the optical tributaries of the gate can be realized by means of an optical amplification device that is fixed or can be regulated, e.g., with SOA (Semiconductor Optical Amplifier) technology, EDGA (Erbium Doped Fiber Amplifier) or by fiber. The amplification at the optical gate output permitting the adaptation of the optical level at the line input can be realized by the same means as previously cited.

[0048] The electro-optical by deleting device can be either a direct modulation of the laser source or a modulation of the light source by means of an electro-optical modulator of the LiNO₃ type or by electro-absorption. The two modulator types have the advantage of being inexpensive.

[0049] Synchronization block 2 can either be autonomous with its own oscillator or connected to an external reference. The clock resulting from the choice of one of these two sources serves as a low-frequency pilot for the high-frequency PLL that procures the cutting signal on optical gate 1. The phase locked loop (PLL) of synchronization block 2 also supplies the synchronization signal for each of transmitters 4. It also makes the phase adjustment for each of the paths in order to compensate the aging of the optical fiber, of the demultiplexer and of the transmitter.

[0050] Signal processing block 3 has the function of creating disturbances marked for each transmission channel. It also permits a spectral analysis of the markers after transformation through optical gate 1. This analysis is performed by rapid Fourier transform and by digital filtering. It also performs the automatic control [slaving] of the transmitters by the PID (Proportional, Interval, Derivative) According to a method, that adjusts the points measured to a set of set points.

[0051] The disturbers are applied on the delay elements of the synchronization block ($\theta_1, \theta_2, \dots, \theta_n$). These disturbers are specific modifications of the phase or of the amplitude of the signals as a function of the transmission channel. Since these disturbers are applied at the level of the delay lines and not at the level of the transponders, the operation is carried out with a low output [rate], thus reducing the cost of implementation. According to a preferred embodiment, these are signals with a determined spectrum, one for each channel to be marked. This spectrum can also be a function of the characteristics of the disturbances undergone by the signal on each path. Moreover, after passing through the optical gate, this marking by disturbers must not modify the information. The latter is therefore filtered at the level of the optical gate.

[0052] The information transmitted from the digital signal processor, DSP, or signal processing unit 8 to the delay lines ($\theta_1, \theta_2, \dots, \theta_n$) comprises the phase control resulting from the PID and the various disturbers stemming from n distinct digital/analog converters 7. The data is received by the DSP after opto-electronic conversion by converter 10 and digitization by analog/digital converter 9.

[0053] Furthermore, signal processing block 3 permits an analysis of the marked signals in order to adjust the phases of each path. This analysis is a spectral analysis of the specific markers and a detection of these markers in the main signal.

[0054] Optical gate 1 comprises an electro-optical modulator, e.g., of the Mach-Zehnder type. The optical stream from the transponder modulated by the data to be transmitted is of the NRZ (non-return to zero) type. The NRZ coding is a type of binary coding in which, e.g., the 0 is represented by a voltage of 0 volts and the 1 by V volts. The NRZ format is very sensitive to optical noises and to non-linearities, in contrast to the RZ symmetric coding (return to zero), in which the 0 is coded by 0 V and the 1 by a transition from V volts to 0 volts. The RZ coding is particularly adapted to long-distance transmissions. This type of coding is also less expensive as concerns the equipment. Optical gate 1 performs the conversion of the NRZ coding into RZ permitting a robust transmission. The use of a modulator permitting a phase inversion of the optical signal, as is the case for the Mach-Zehnder, also authorizes the implementation of the CS-RZ (carrier suppression RZ) format. This format, obtained by applying one half the frequency applied in the case of the RZ modulation on the optical gate, has the advantage of the spectral width of the NRZ format and the advantage of the robustness to noise of the RZ format.

[0055] Figure 5 shows the different representations of the data for the transmission. In this case the RZ signal is obtained by cutting the NRZ sequence of at least one clock with a period

identical to that of the binary element of the stream to be modulated with the aid of the external modulator.

[0056] Moreover, optical gate 1 performs an optimization of the optical parameters of the signal received, in particular in the form of a reduction of the signal chirp.

[0057] Finally, optical gate 1 performs an operation of stabilizing the time division [timing] parameters of the data stream, in particular in the form of a reduction of the jitter of the modulating signal.

[0058] These two operations of the stabilization of the time division parameters and of the optimization of the optical parameters significantly improve the quality of the transmission after passage through the optical gate.

[0059] Note that the invention can also be used for signal regeneration on an optical line. This is done by adding the elements described below as in figure 4.

[0060] The highest degree of regeneration, called 3R regeneration, involves a re-formatting [re-shaping] of impulses in the area of the amplitude (2R regeneration for re-amplification and re-shaping) and in the re-timing area. At the level of the regeneration site a demultiplexer permits the separation of the signals to be regenerated (after a loss of level or a chromatic dispersion). The signals pass through opto-electric (O/E) converters. The realignments of the signals are then carried out by the equipment of the invention described above and the master clock PLL is fed by a new reference clock 13 defined by the analysis of one of the signals.

[0061] According to a variant, several signals are analyzed and the clock will be defined by the best signal obtained.

[0062] The opto-electric converters are then connected to n transponders and to the equipment described in figure 3, comprising optical gate 1, synchronization block 2 and signal processing block 3.

[0063] It is appropriate to note that the delays introduced by this regeneration mode are of the electric type following the optical-electronic conversion.

[0064] The invention is described above by way of example. It is understood that an expert in the art is capable of realizing different variants of the invention without departing from the scope of the patent.